

Drought Prediction: The Role and Predictability of Stationary Rossby Waves

Siegfried Schubert, Yehui Chang*, Hailan Wang**, Randy Koster,
and Max Suarez

Global Modeling and Assimilation Office
NASA/GSFC

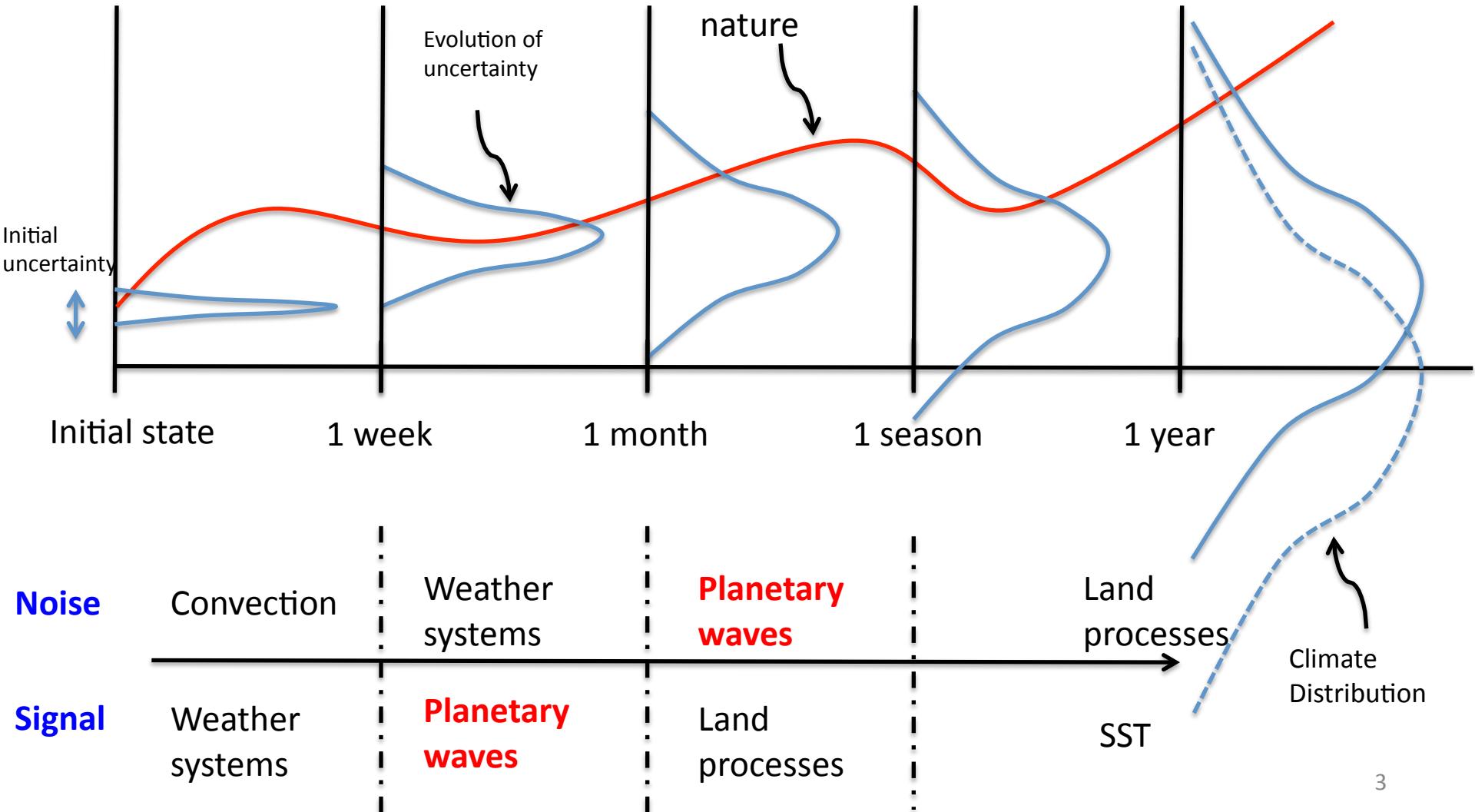
* Also, GESTAR, Morgan State University, Baltimore, Maryland

**Also, Science Systems and Applications Inc. (SSAI)

Understanding Sources of Predictability

- *SST controls*
- *Land impacts*
- *Large-scale (internal) atmospheric dynamical controls*

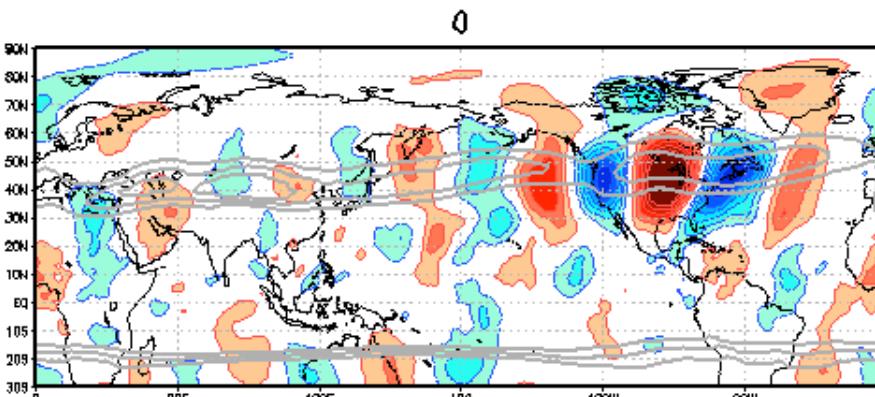
Predictability



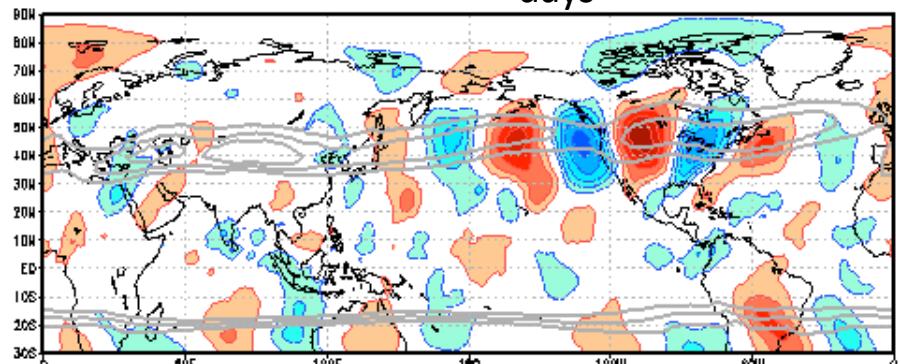
Summertime Rossby Waves

- *Determine basic structure of the leading waves*
- *Determine impacts on precipitation and surface temperature*
- *What forces the waves?*
- *How predictable are they? (case studies of extreme events)*

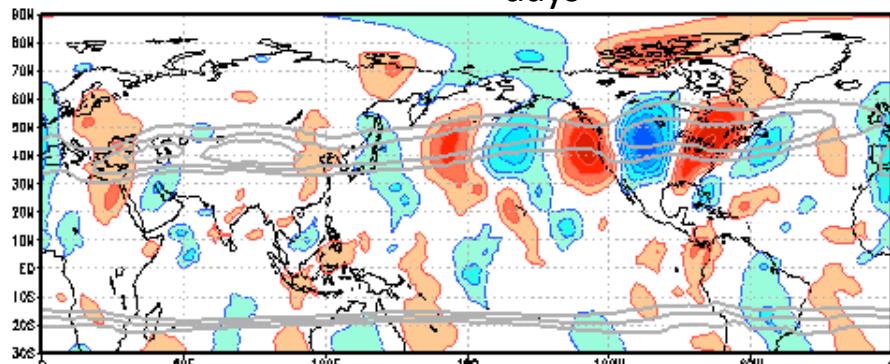
One-point Lead/Lag Corr(v250,v250_GP); 10–30 Day Digital Filter
Jun1979–2008



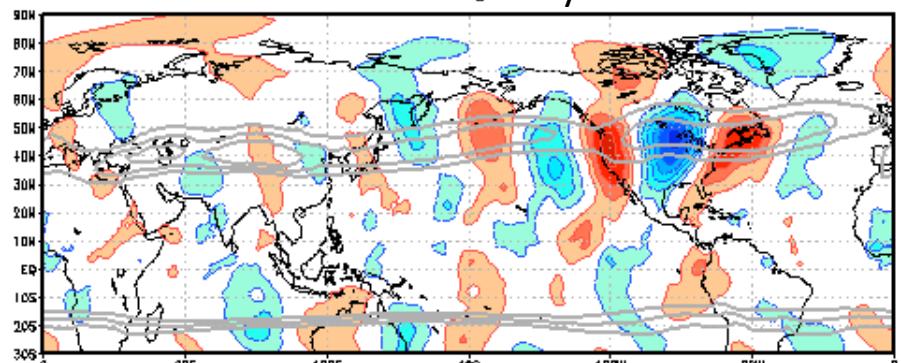
-4 days



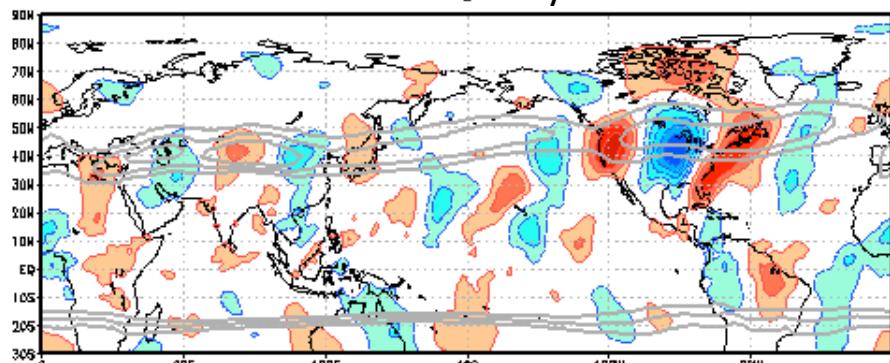
4 days



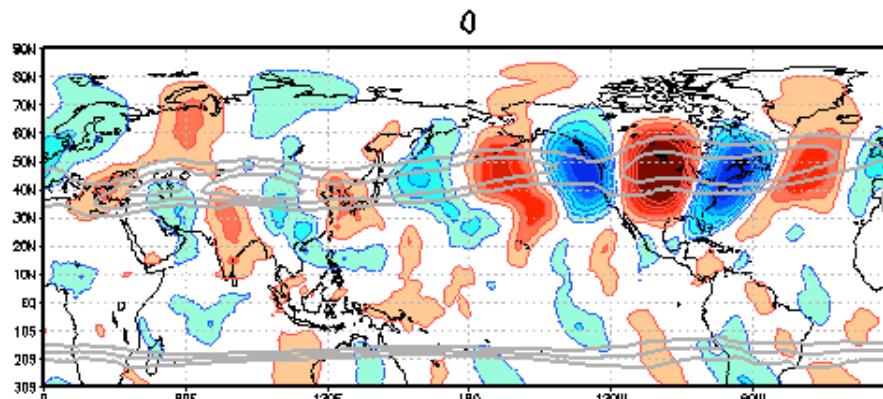
-8 days



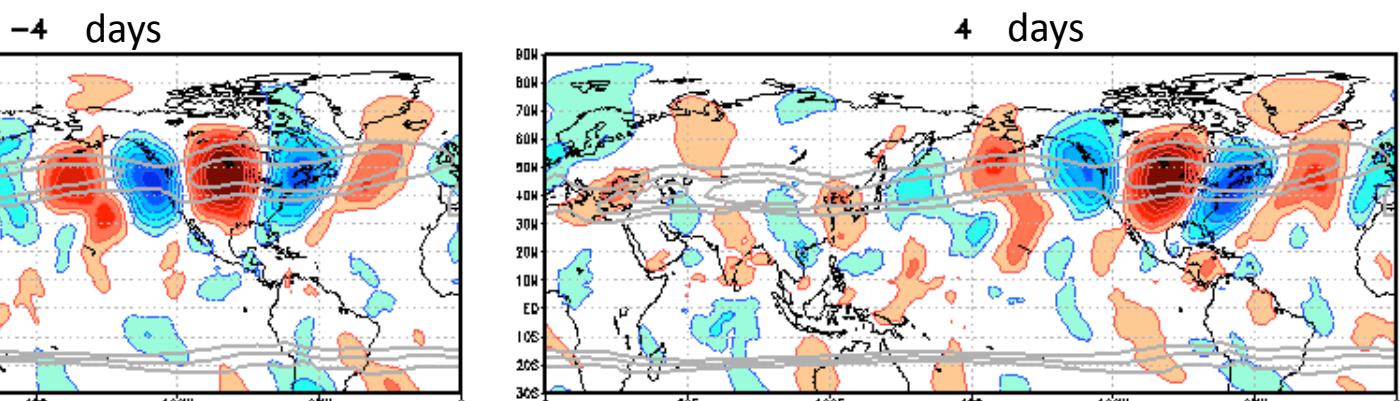
8 days



One-point Lead/Lag Corr(v250,v250_nGP); 30–90 Day Digital Filter
JJA1979–2008

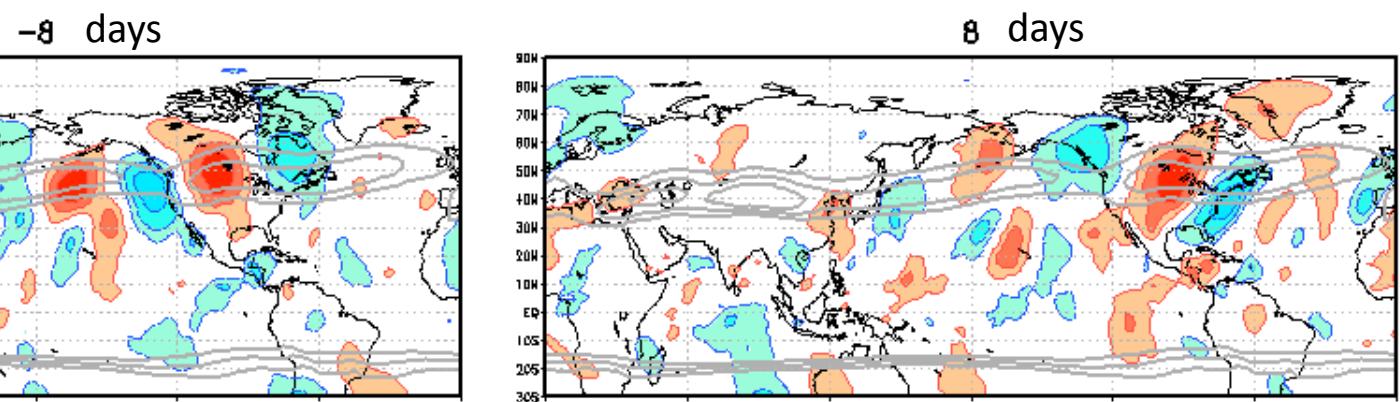


-4 days



4 days

-8 days



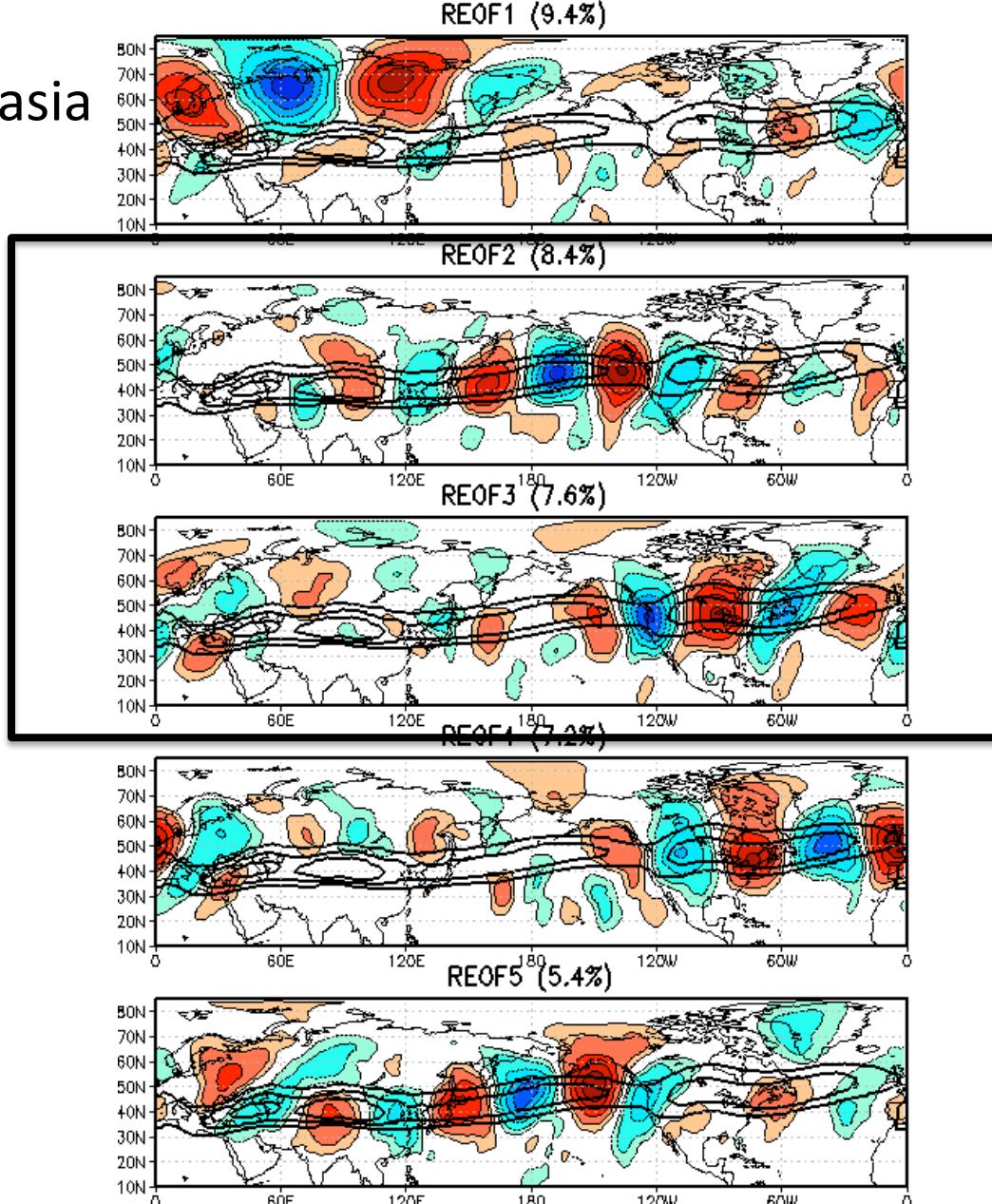
8 days



6

Leading REOFs of Monthly v250mb (JJA 1979-2010)

Impacts Eurasia

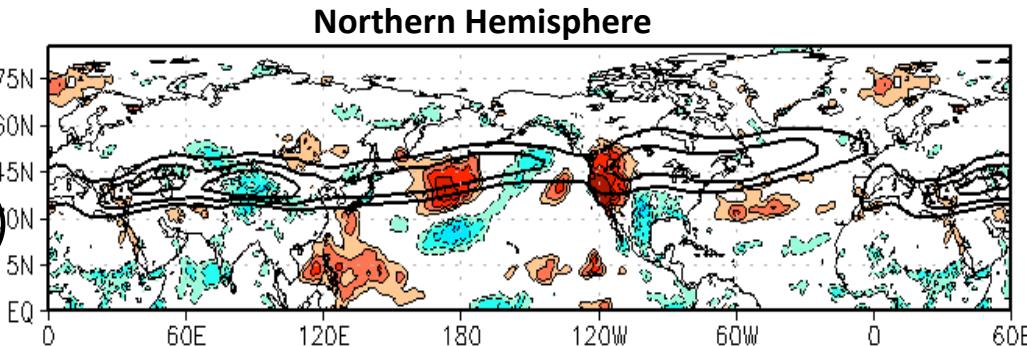


Will focus on
these two leading
patterns (REOFs 2
and 3)

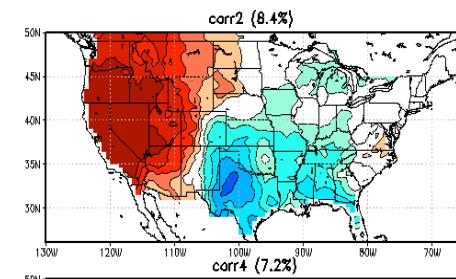
Impacts on Surface Meteorology

JJA 1979-2010 (monthly)

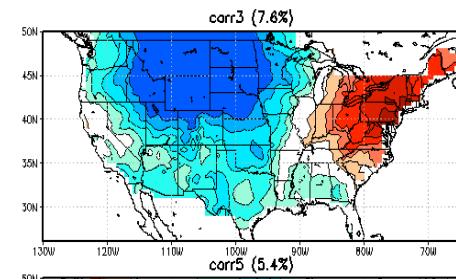
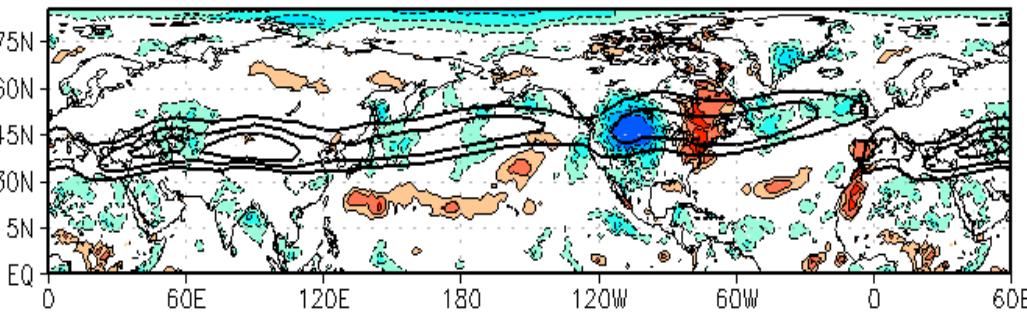
Corr (RPC2, T2m)



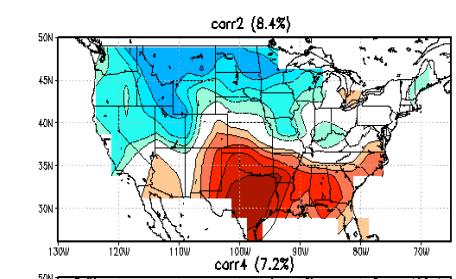
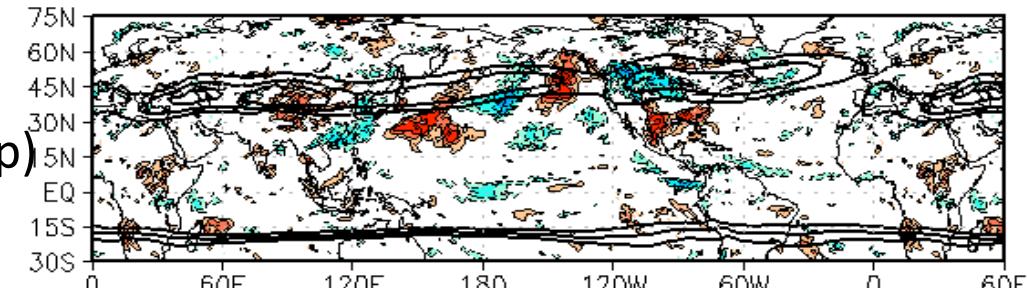
Over the US



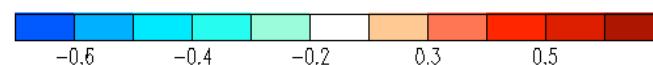
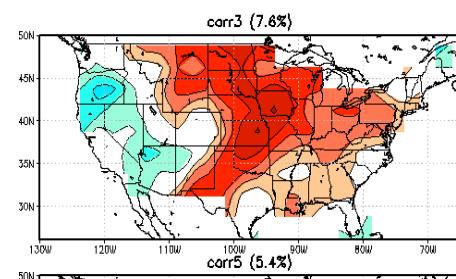
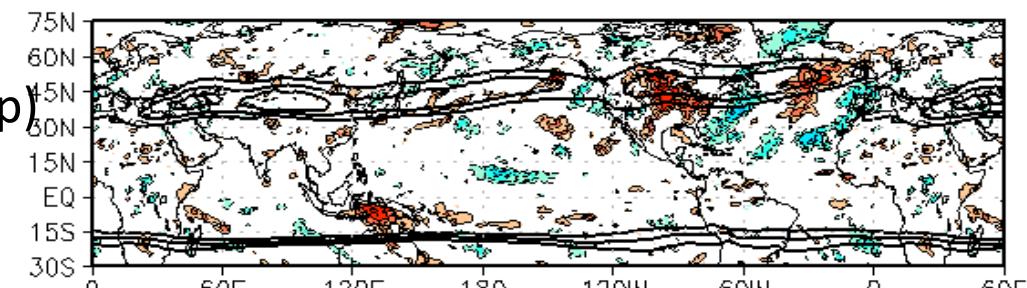
Corr(RPC3, T2m)



Corr(RPC2, Precip)



Corr(RPC3, Precip)

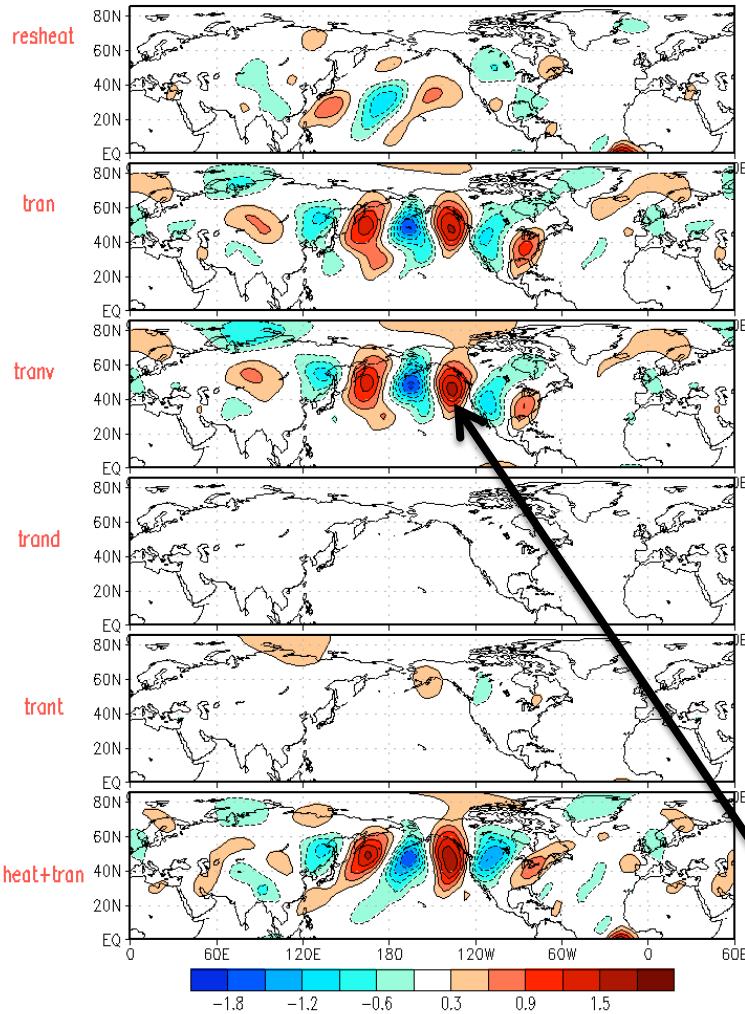


What forces these Waves?

Stationary Wave Model* Diagnosis of Forcing (MERRA Base State JJA 1979-2008)

REOF 2

EddyV response at Sigma=0.257 to regr(forcing, rpcs2_V250)
MERRA(1979-2008); JJA mean removed



REOF 3

EddyV response at Sigma=0.257 to regr(forcing, rpcs3_V250)
MERRA(1979-2008); JJA mean removed

Diabatic heating

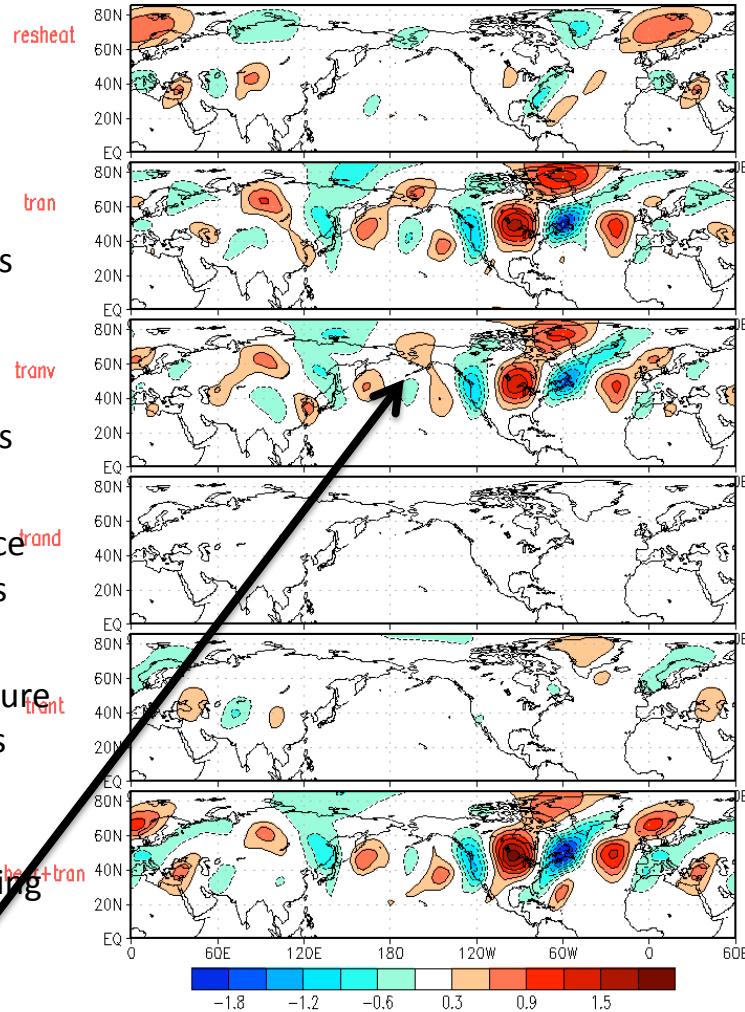
Total transients

Vorticity transients

Divergence^{trand} transients

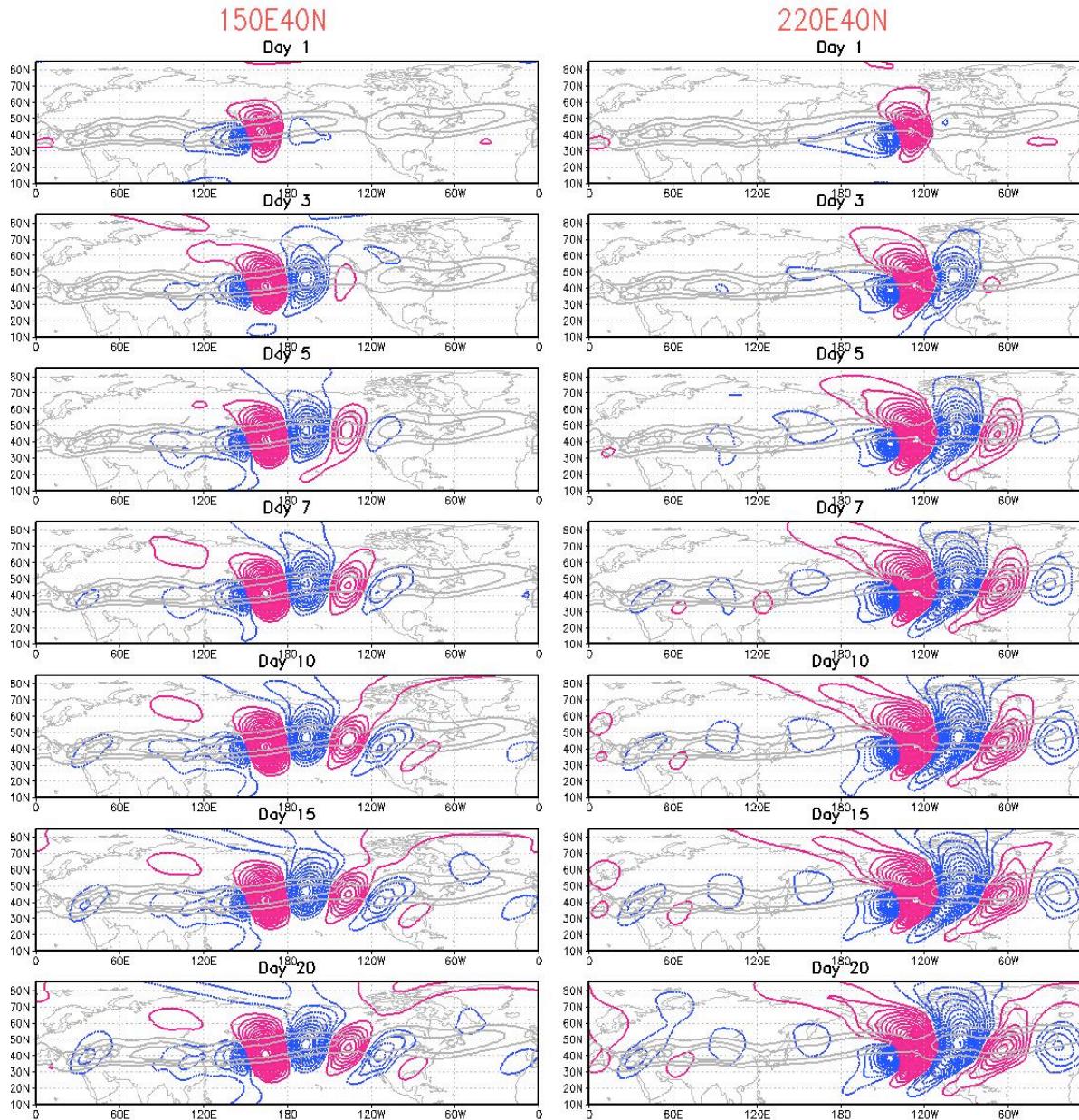
Temperature^{trant} transients

Total forcing^{heat+tran}



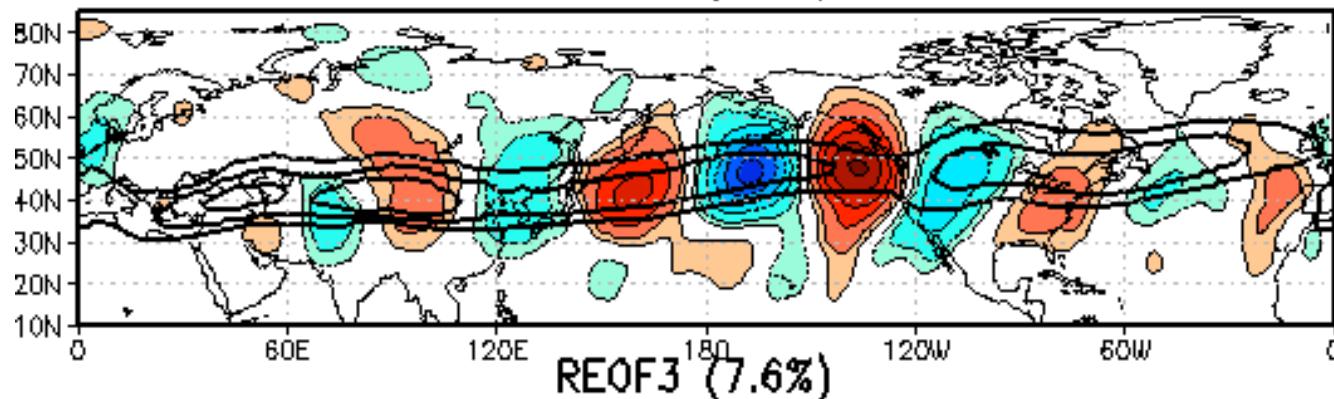
V ($\sigma=0.257$) Responses to Idealized Vorticity Sources

(Stationary Wave Model: MERRA Base State JJA 1979-2008)

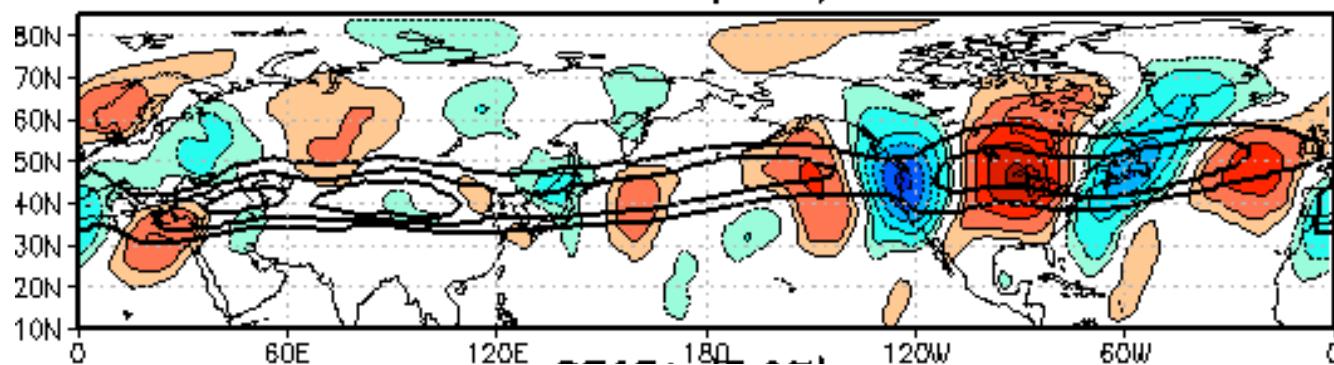


Focus on A Couple of Cases Where these Waves
Achieve Large Amplitude

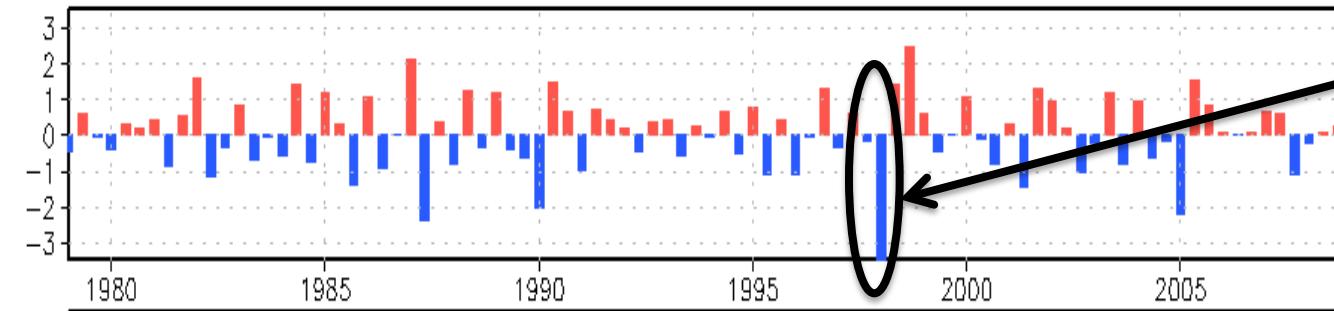
REOF 2



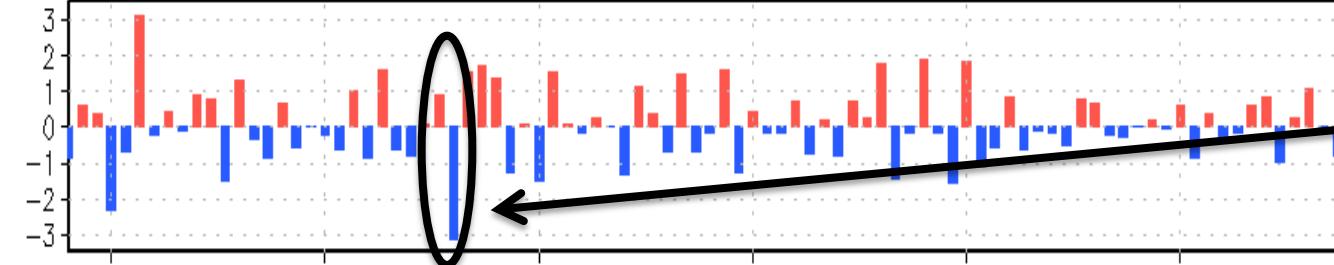
REOF 3



RPC 2

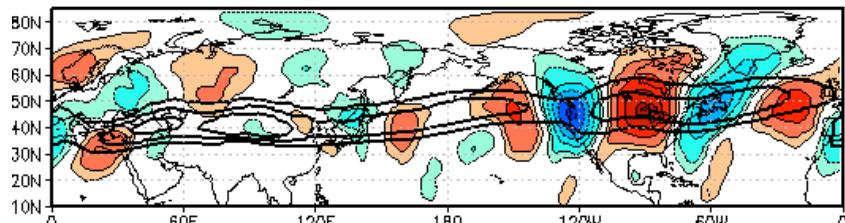


RPC 3

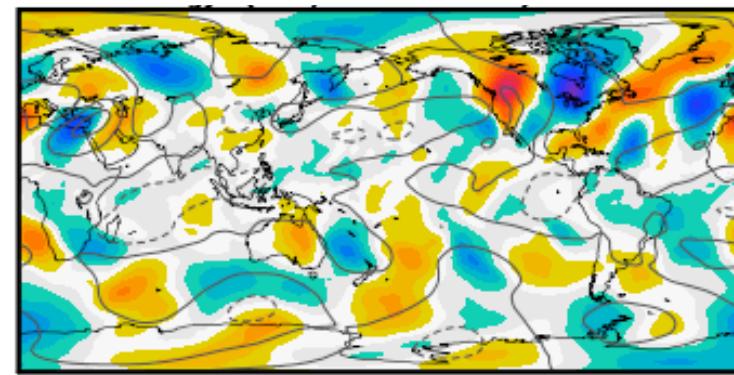


REOFs Versus Actual Anomalies (V250mb)

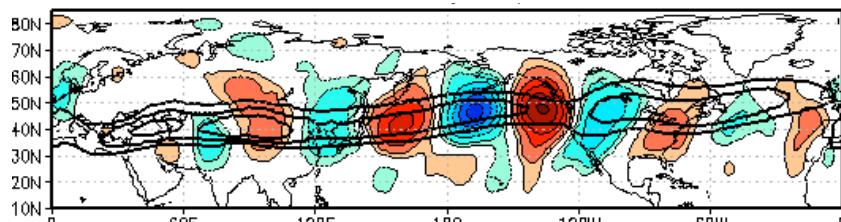
REOF 3



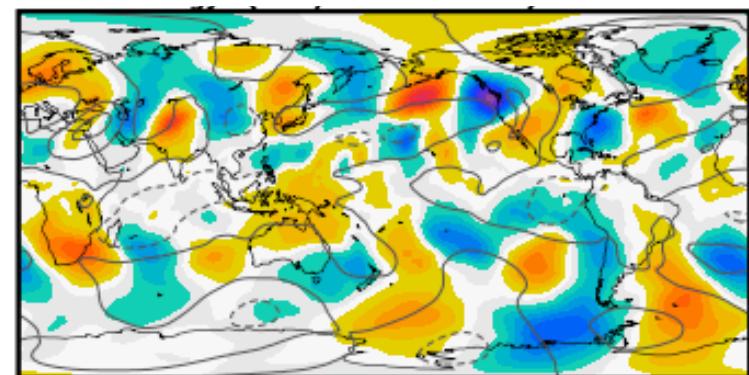
June 1988 Anomalies - MERRA

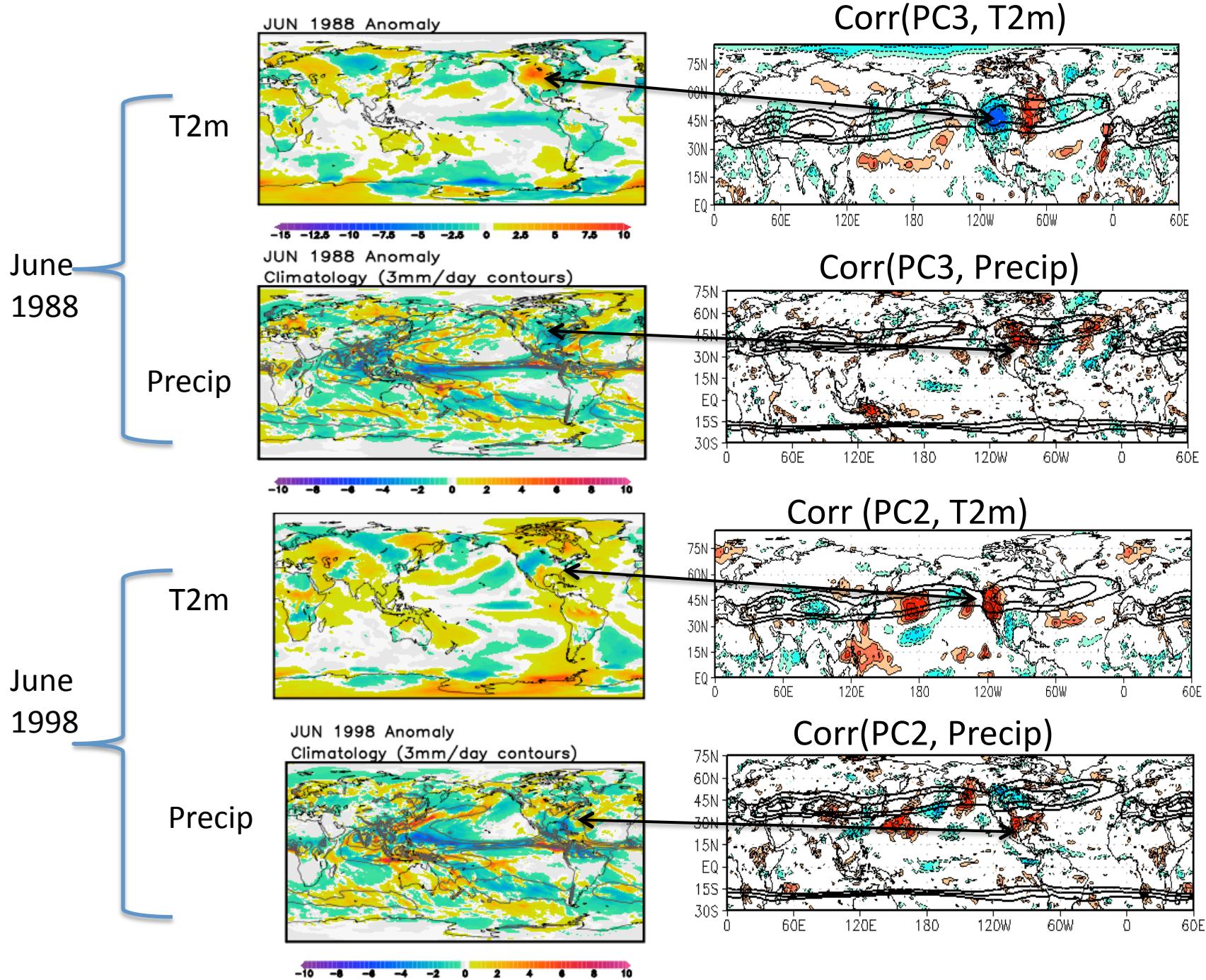


REOF 2



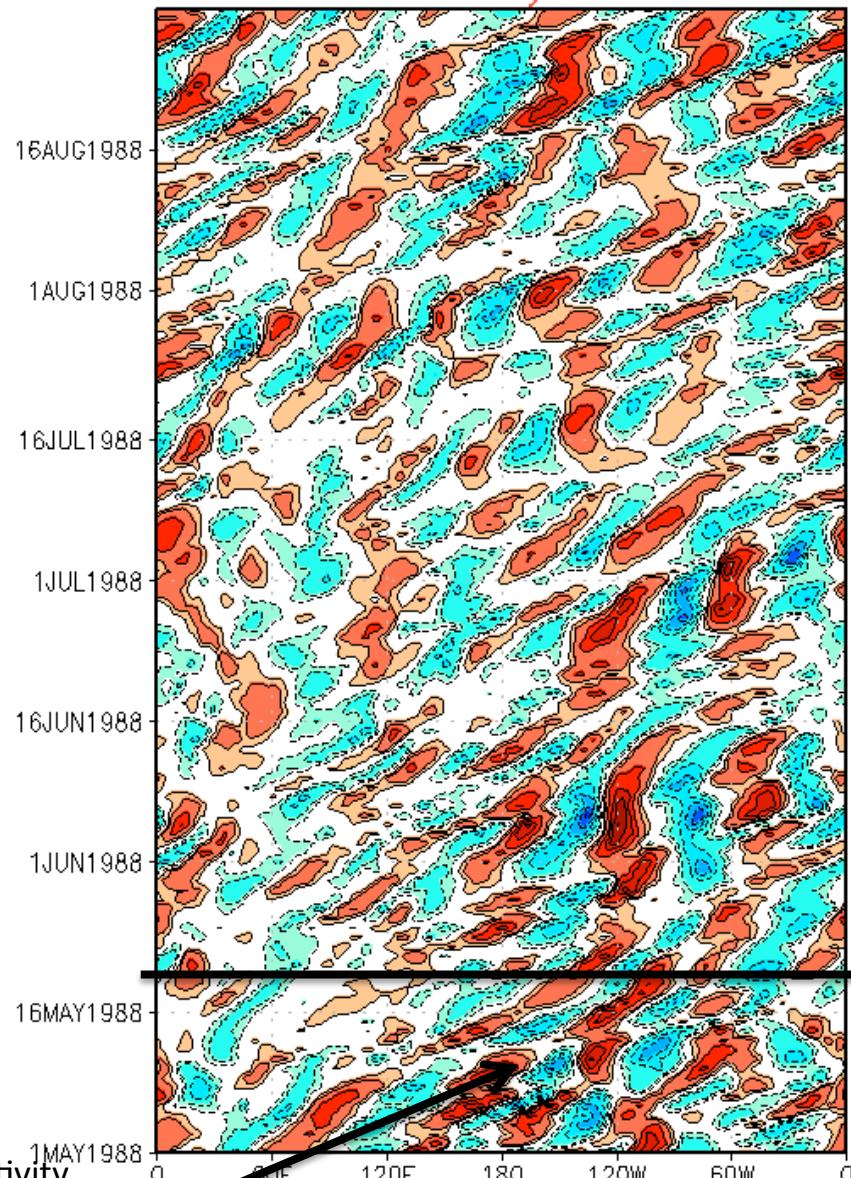
June 1998 Anomalies - MERRA



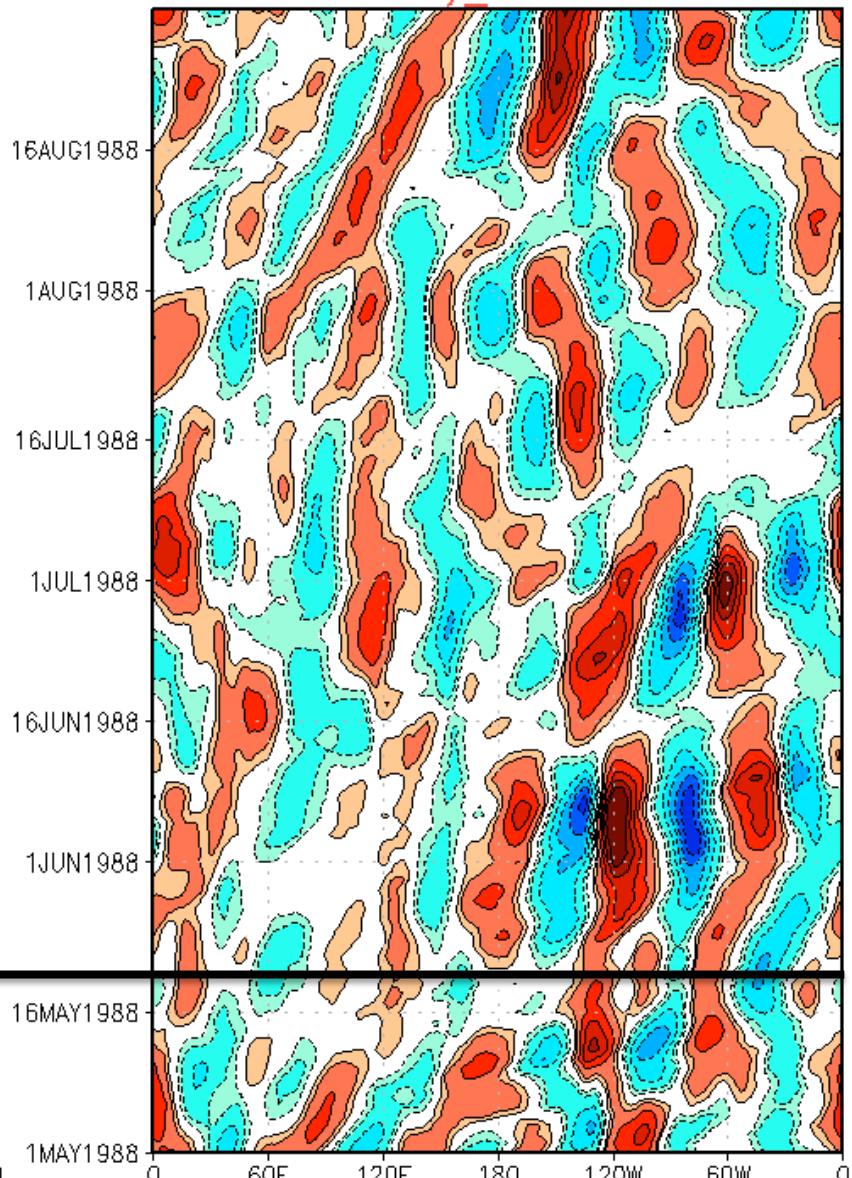


Temporal Evolution of V250mb(40N–60N): 1988

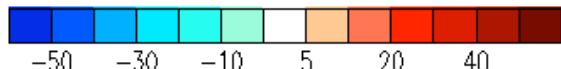
Daily



9day smooth

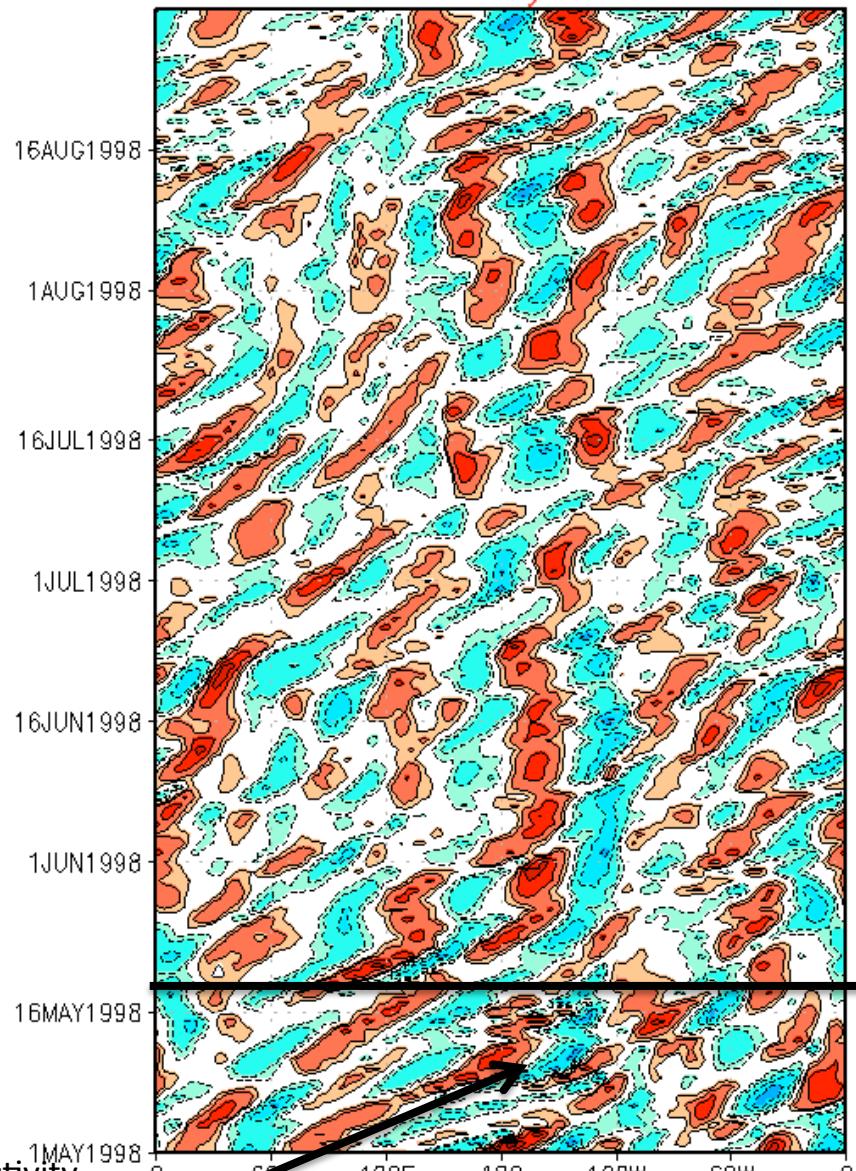


Synoptic activity
precedes stationary
phase

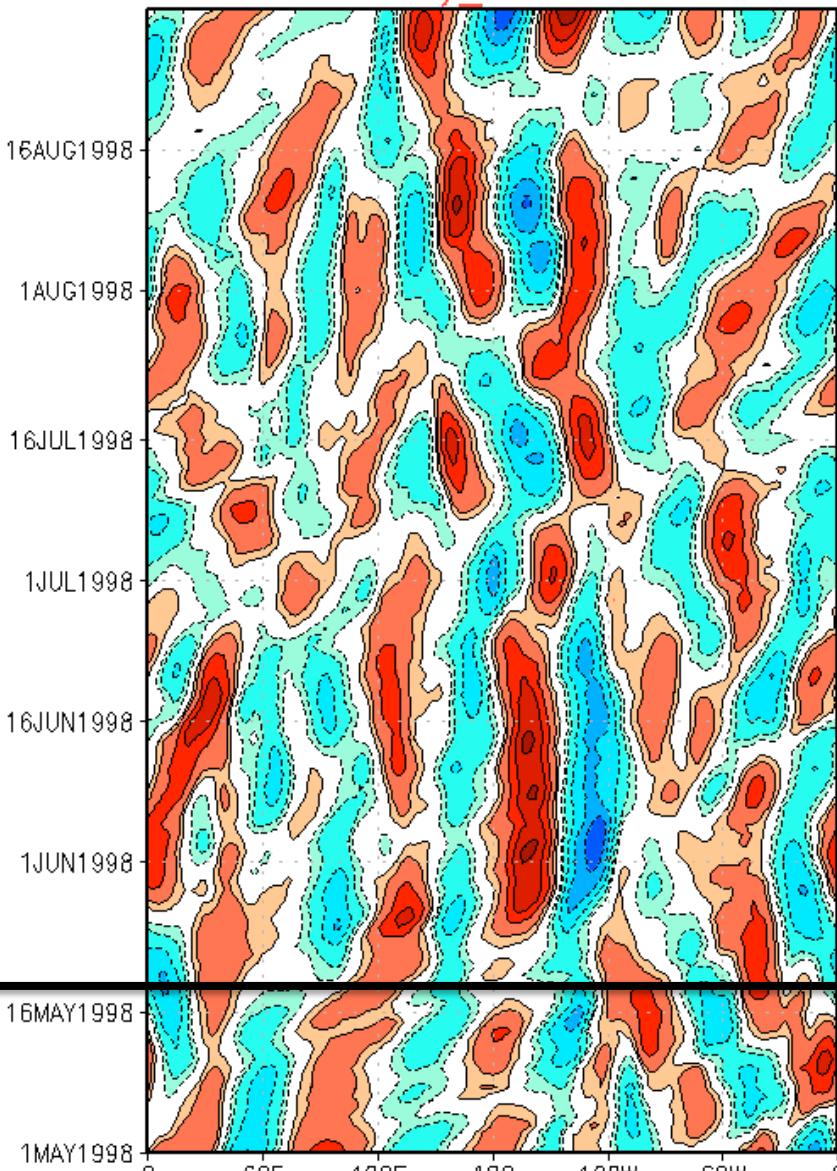


Temporal Evolution of V250mb(40N-60N): 1998

Daily



9day smooth



Synoptic activity
precedes stationary
phase



Summary so far

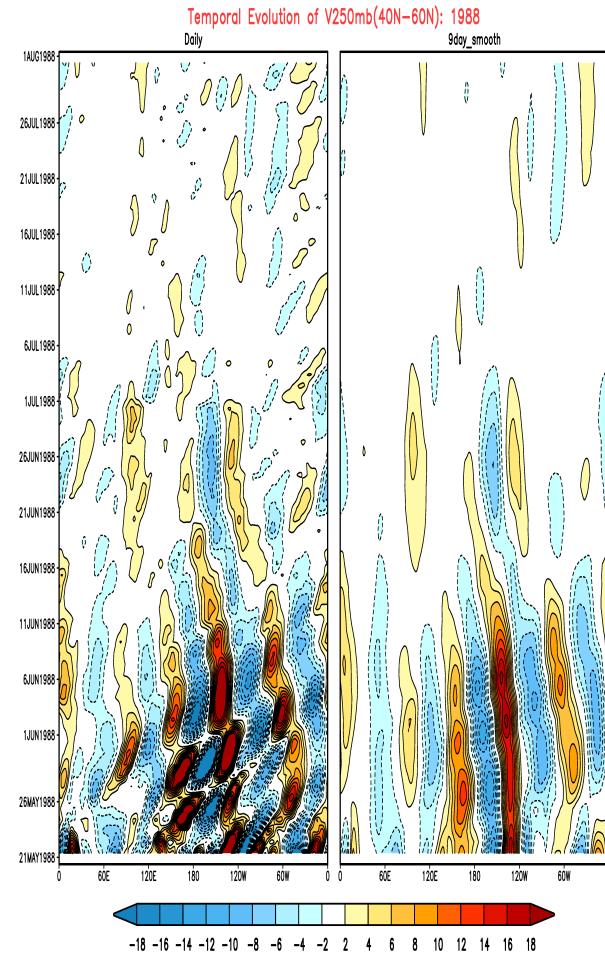
- Leading REOFS reflect stationary Rossby Waves (wave number 6) that tend to be confined to the mean jet which acts as a wave guide
- These appear to be major players in monthly extremes of surface temperature and precipitation over a number of regions of the NH middle latitudes including parts of North America
- They appear to be primarily forced by submonthly vorticity transients
- How predictable are they?

Predictability Experiments with GEOS-5 AGCM

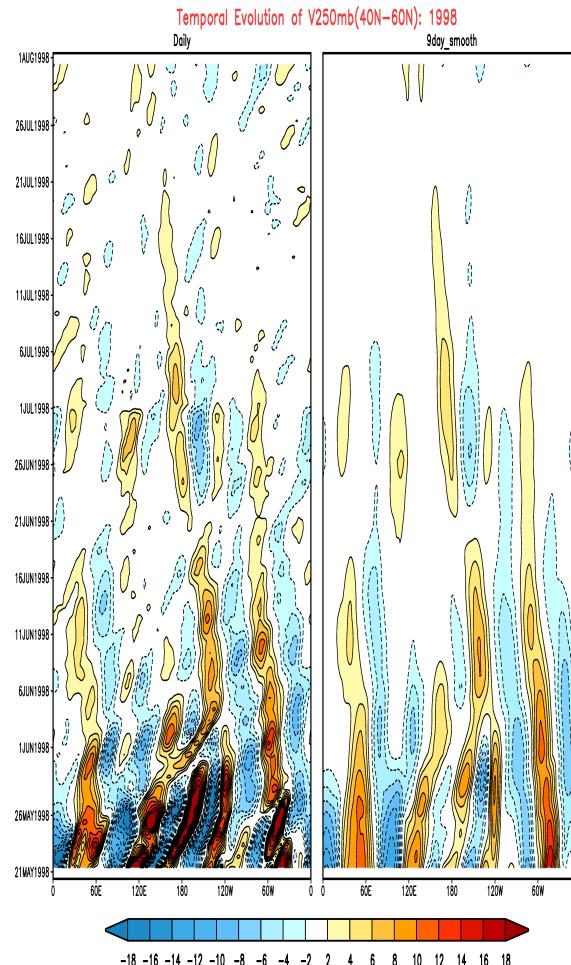
- June 1988
- June 1998
- *June 2012 (just recently added this case for comparison)*
- Produce an ensemble of 32 runs initialized on May 20th for each case (small initial atmospheric perturbations)
- Forced with observed SST

Ensemble Mean v250mb

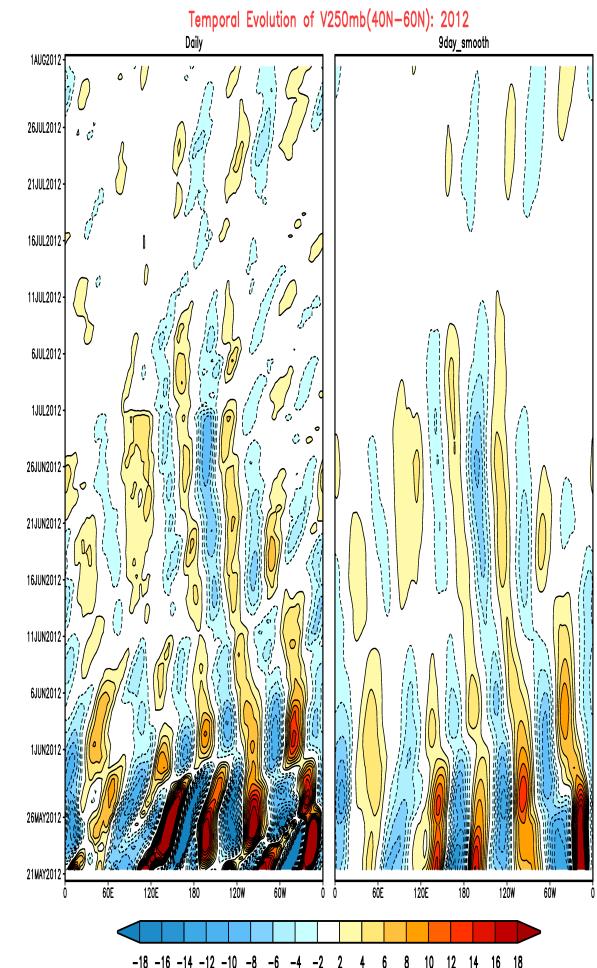
1988



1998



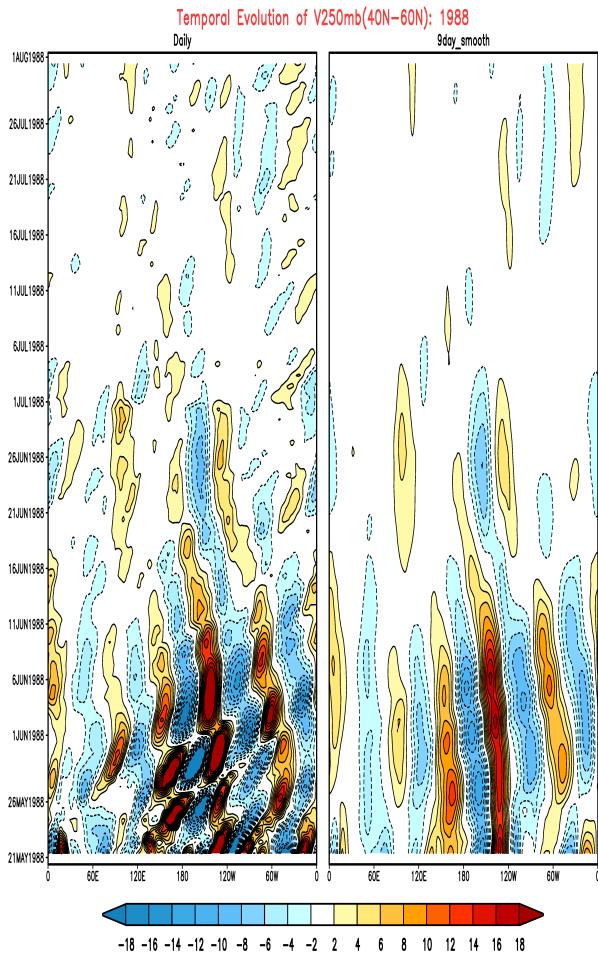
2012



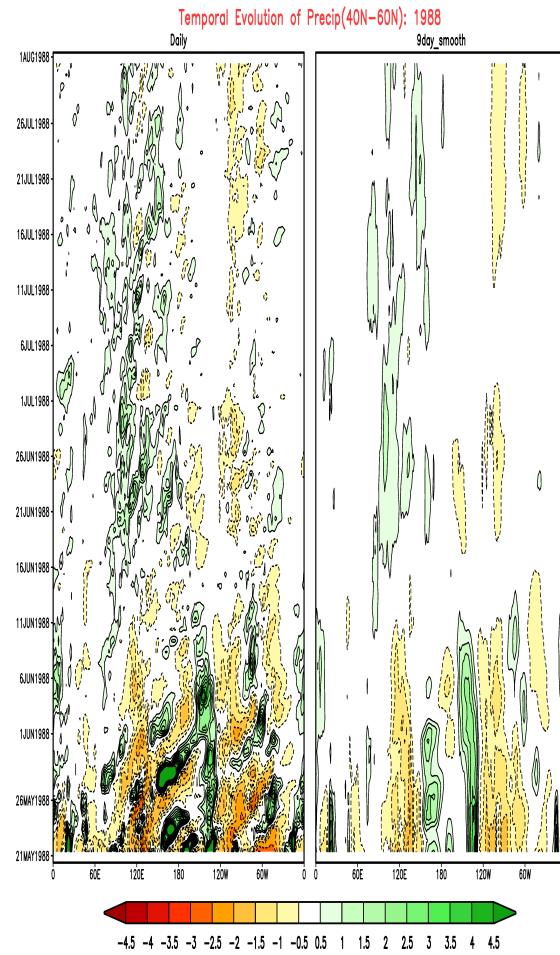
Predictability (signal) extends into late June/early July (some tendency for waves to retrograde)

Focus on 1988- Ensemble Mean

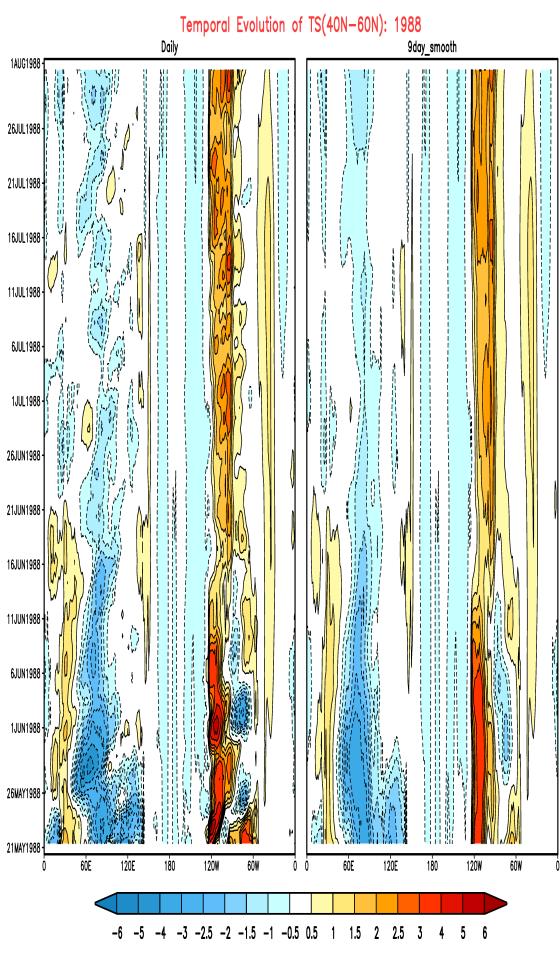
v250mb



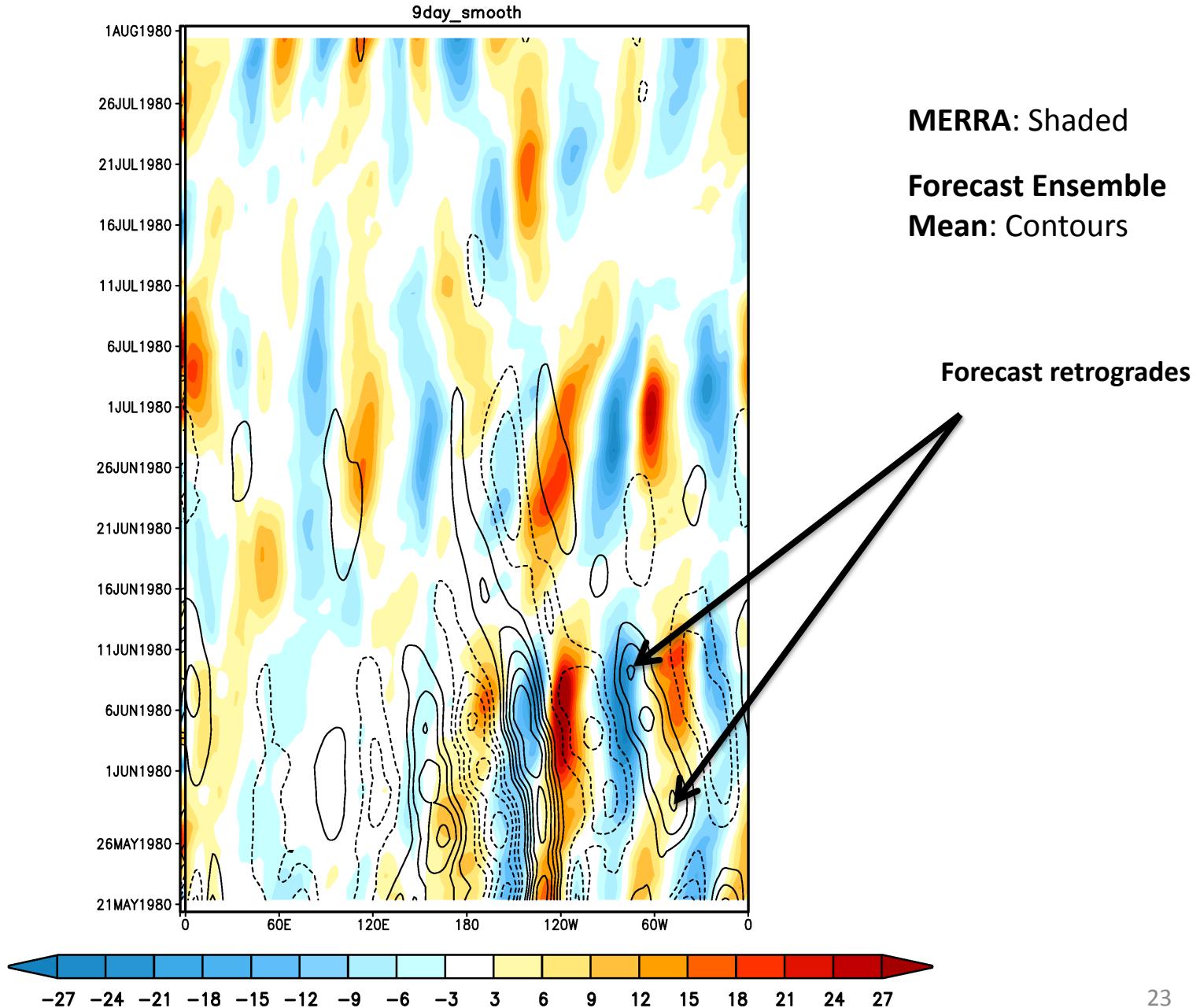
Precipitation



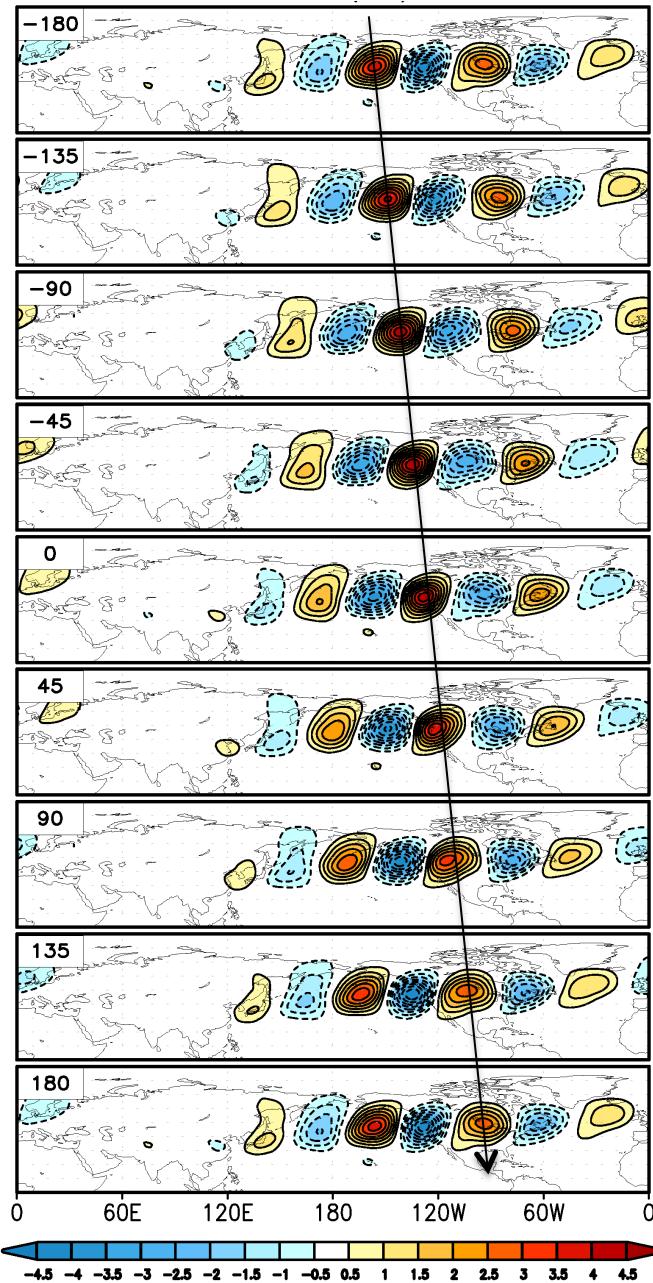
T2m



Focus on 1988



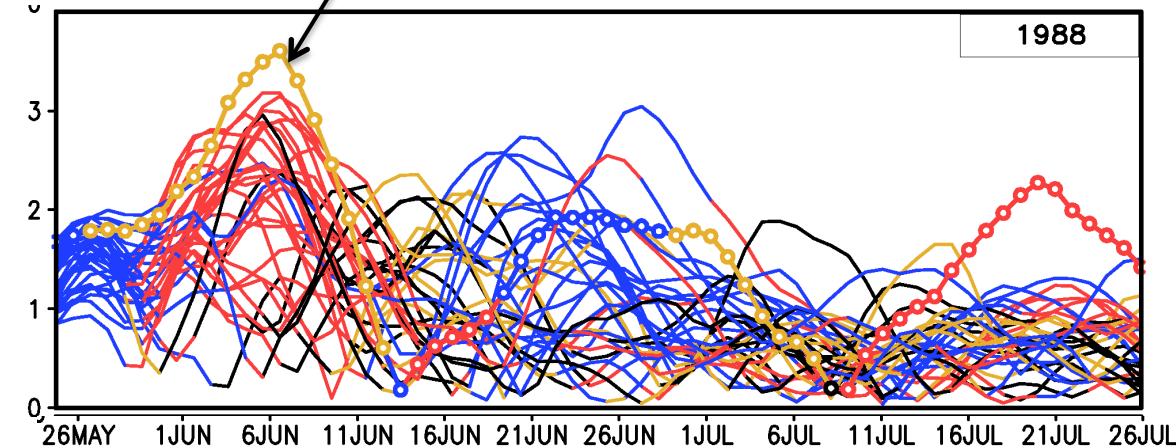
REOF 1 (12%)



RPC 1: 1988

MERRA (line with circles) is an outlier of the model distribution

$-135 < \text{phase} < -45$ $-45 < \text{phase} < 45$ $45 < \text{phase} < 135$ $135 < \text{phase} < 225$



RPC 1 amplitude for all ensemble members and MERRA (circles). Color indicates the phase of the complex REOF 1 (at left). Note the significant predictability extending well into June, but the forecast wave retrogrades (propagates to the west – blue to red color), while the observations show an eastward propagation (blue to gold color). Forecasts were initialized on May 20 (21z).

Conclusions

- Rossby waves play a pivotal role in summertime surface temperature and precipitation variability over NH middle latitudes on subseasonal time scales
- They are at times (on subseasonal time scales) the primary driver of temperature and precipitation extremes
- They have some predictability on monthly and shorter time scales, but appear to be unpredictable at seasonal and longer time scales (they are likely the largest contributors to the noise in seasonal forecasts in the summer)
- Model deficiencies (likely tied to errors in the summertime mean jets) currently limit the skill that could potentially be harvested from these waves.
- The extent to which these waves are modulated by the land surface (soil moisture anomalies), SSTs, and global warming is still unclear (focus of on-going work).